DEFORMATION IN THE CASA DIABLO GEOTHERMAL WELL FIELD, LONG VALLEY CALDERA, EASTERN CALIFORNIA

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Two sources of stress are producing deformation in the Casa Diablo geothermal well field. Magmatic intrusions reaching shallow depths in the crust are causing regional inflation over a broad area that includes the well field. Pumping and injection of geothermal fluids for electric power generation are causing subsidence locally around the well field.

The Casa Diablo well field lies within a northwest-trending graben on the southwestern edge of the resurgent dome in the Long Valley caldera (fig. 1). Episodes of anomalous seismicity and deformation beginning in 1980 are likely caused by episodic intrusions of magma beneath the resurgent dome (Langbein and others, 1990, and Langbein and others, 1993). Results of differential leveling along U.S. Highway 395 during the period 1975–92 show that the land surface in the Casa Diablo area of the resurgent dome was elevated by about 2 ft (Savage, 1988, and D. Dzurisin, U.S. Geological Survey, written commun., 1993).

Electric power generation using geothermal fluids from the Casa Diablo field began in 1985 with one binary powerplant (MP I). Two additional powerplants (MP II and MP III) were put on line in December 1990. The power-generation process cools the geothermal fluid by about 60 ^{o}C in a closed-loop system. All the fluid that is pumped from wells on the western side of the well field from depths of about 500 ft is injected on the eastern side of the field at depths that have ranged from about 1,500 to 2,500 ft. In July 1991, shallow perforated sections in all injection wells were sealed, forcing injection of fluids to depths greater than 2,000 ft.

In 1985 localized subsidence around Casa Diablo began to counter the uplift of the well field area caused from magmatic intrusions under the resurgent dome. This local subsidence began within about 6 months of the start of geothermal fluid pumping at Casa Diablo. Results from leveling surveys show that Casa Diablo subsided about 0.38 ft between 1988 and 1992 relative to bench marks outside the area of subsidence, which had risen about 0.34 ft.

Each of the following processes may be occurring and causing deformation related to the geothermal operation: subsidence and inflation caused by changes in pore pressures in the production and injection reservoirs and adjacent formations, expansion and contraction of rocks caused by temperature changes in the reservoirs and overlying formations, and subsidence from loss of mass caused by escape of steam from boiling zones.

Data from the “L-shaped tilt array,” a network of closely spaced bench marks along two nearly perpendicular legs (see fig. 1) are shown in figure 2 as north and east components of tilt in microradians per year. The first significant tilt began in 1985 after the start-up of MP I. The downward tilt to the north increased by a factor of about three following a fourfold increase in pumping when power plants MP II and III were started in December 1990.

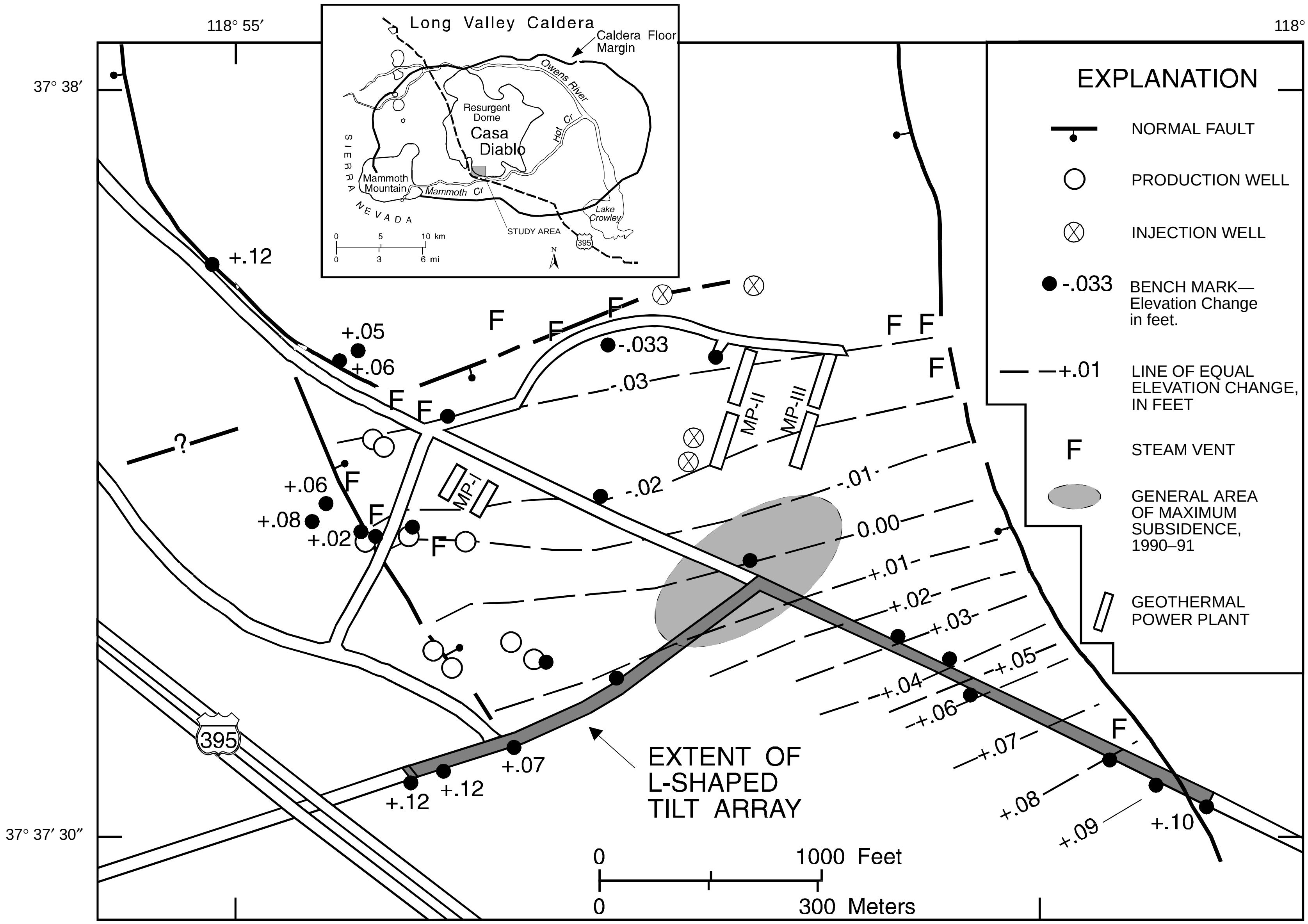

Figure 1. Elevation changes at Casa Diablo, 1991–92. Insert shows location of the Casa Diablo study area within the Long Valley caldera.

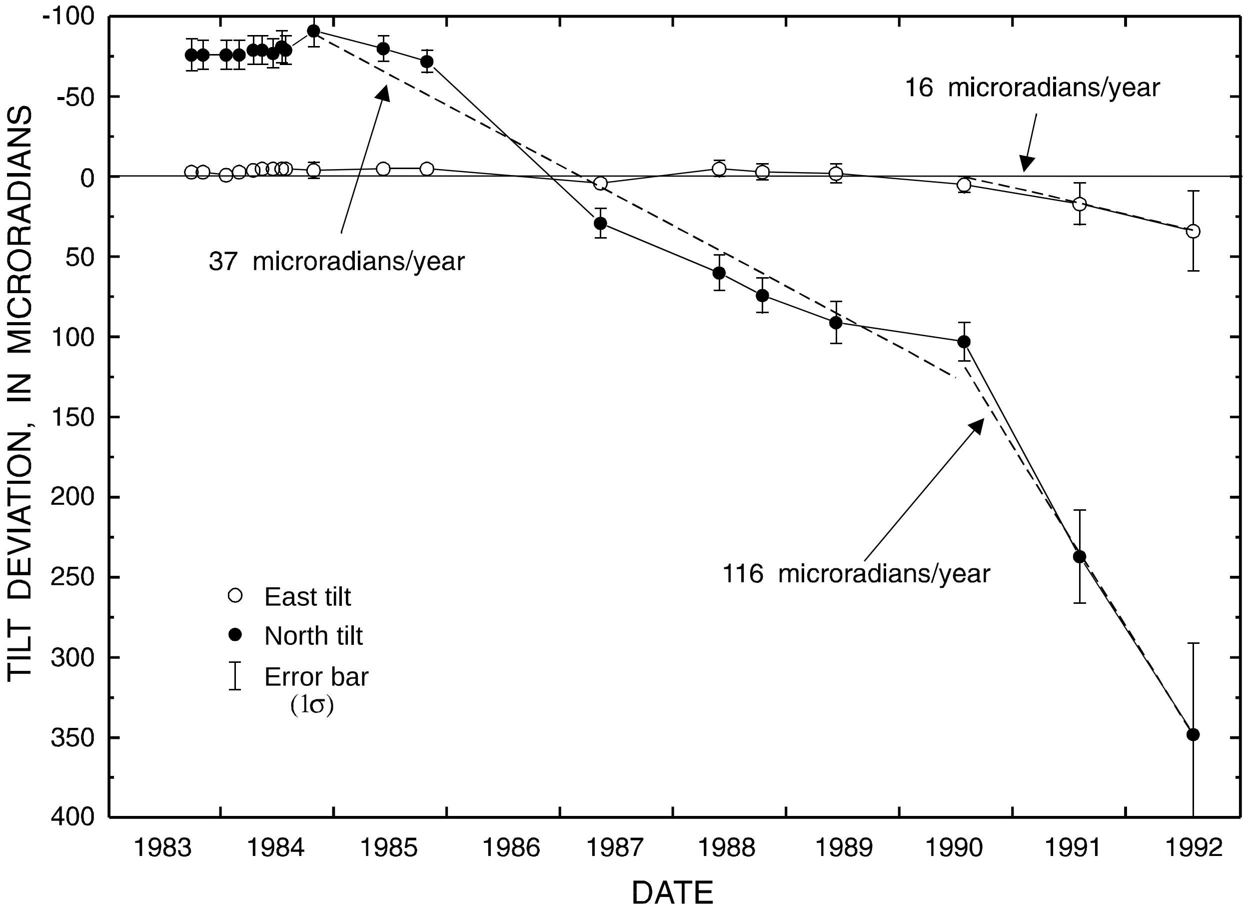

Figure 2. Calculated tilt from elevation changes along L-shaped bench-mark array at Casa Diablo. Dashed lines show average tilt per year for 1984–90 and 1990–92.

In June 1988 a network of bench marks was established in the well field to provide for more detailed measurement of deformation caused by pumping geothermal fluids (see Ikehara #1 abstract). Data from this network show that prior to 1992 the location of maximum subsidence around the well field was east of the production wells (fig. 1). This area is underlain by compressible unsilicified-rhyolite that occurs in the central part of the graben.

In 1992 the area of maximum subsidence shifted to the northwest and now includes both the production and injection sides of the well field. The change may have been brought about by the work done on the injection wells in July 1991, which sealed off shallow zones. The sealing of shallow zones caused the pore pressure in the production reservoir to fall sufficiently to allow boiling in the upper part of the production reservoir and overlying formations. Steam from the boiling process can escape to the atmosphere along faults and fracture zones. Steam discharge around the well field was noted to have increased significantly during 1991. Subsidence is uniform across the well field from injection to production sides, making it unlikely that thermal-elastic effects are responsible for the deformation observed between 1991 and 1992. It is probable that the greater degree of isolation of the injection and production reservoirs brought about by sealing off the shallow injection zones has allowed the pressure-drop in the production reservoir to spread across the well field to include the injection and production sides.

The two northwest-trending graben-bounding faults and the northeast-trending cross-fault (fig. 1) may exert some control over the spread of subsidence away from the well field. Changes in bench mark elevations between 1991 and 1992 suggest that the floor of the graben is pivoting downward to the northwest. Changes in pore pressure along the fault planes in response to fluid injection may be decreasing the coefficient of friction, thereby facilitating slippage along the faults.